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EFFICIENCY OF INLINE FILTERS IN CLEANING CONDENSER EXHAUSTS AT COTTON GINS

Laboratory Evaluation of Southeastern Conditions

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EFFICIENCY OF INLINE FILTERS IN CLEANING CONDENSER EXHAUSTS AT COTTON GINS

Laboratory Evaluation of Southeastern Conditions

By Richard A. Wesley,[1] Joseph B. Cocke,[2] and Warren E. Garner[1]

ABSTRACT

Inline filters satisfactorily collected dust and lint fly from condenser exhausts during a 2-year experiment. Average cleaning efficiency varied from 75.8 to 86.4 percent. Filter efficiency in the battery condenser averaged 87.6 percent. Collection efficiency was not significantly affected by inlet dust concentration, ginning rate, cotton variety, or filter location. The filters collected almost all lint fly.

INTRODUCTION

Dust and lint fly have long been problems for the cotton ginner. Community pressure and tightened legal restrictions on the emissions from cotton gins provided the impetus for increased efforts to abate air pollution from the condenser exhausts of the modern cotton gin.

In the early days of the cotton gin, when most cotton was handpicked and virtually free of waste material, there was no concern about air pollution, and the condensers could exhaust directly into the atmosphere. Even so, as communities enlarged, and in many places eventually surrounded cotton gins, some means of controlling lint fly and dust was required. Early abatement devices developed for condenser exhausts were dust houses or settling chambers and screen wire cages.[3] These devices collected some of the lint fly and dust, but created a fire hazard.

As community demands for air-pollution control increased and as mechanical harvesters replaced handpickers, cotton ginners found it necessary to provide more efficient means of collecting the dust and lint fly. To help meet this requirement, the inline air filter was developed by the Southwestern Cotton Ginning Research Laboratory to remove pollutants from condenser exhausts.[4]

A 2-year study (1970–71) was conducted to determine the operating characteristics of the inline air filter in the presence of gin trash from machine-picked cotton grown in the Southeast.

The 1970 experiment evaluated the performance of the inline filter at different trash input rates. The specific objectives were to determine (1) the average collection efficiency of the inline filter for a range of trash input rates, (2) the effect of inlet dust concentration and ginning rate on the collection efficiency of the filter, and (3) the lint composition of the material entering the inline filter and the efficiency of the filtering unit in collecting lint fly.

The 1971 experiment investigated the efficiency of the inline filter in collecting waste material from different cotton varieties and at various stages of lint cleaning. The specific objectives were to determine (1) the collection efficiency of the inline filter at both lint cleaner and battery condenser exhausts, (2) the effect of cotton variety and inline filter location on collection efficiency, (3) the lint composition of the mass entering the inline filter from the various stages of lint cleaning, and (4) the dust concentration and lint composition (pounds per bale) emitted from the battery condenser to the inline filter, operating after each stage of lint cleaning.

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[3] Harrell, E. A., and Moore, V. P. 1962. Trash collecting systems at cotton gins. U.S. Dep. Agric., Agric. Res. Serv. [Rep.] ARS 42–62, 23 pp.

[4] Alberson, D. M., and Baker, R. V. 1964. An inline filter for collecting cotton gin condenser air pollutants. U.S. Dep. Agric., Agric. Res. Serv. [Rep.] ARS 42–103, 16 pp.

TEST PROCEDURES AND EQUIPMENT

To determine the collection efficiency of the inline filters, two sampling stations (figs. 1 and 2) were required for each condenser exhaust. One station was installed on the inlet side, to determine the dust concentration entering the inline filters; the other was located 15 feet downstream from the filter, to determine the dust concentration escaping into the atmosphere. Each sampling unit consisted of a pitot tube and manometer, a sampling orifice, a high-volume air sampler, and a variable voltage transformer. A barometer and hygrothermograph recorded atmospheric conditions.

The desired intake volume for isokinetic sampling conditions in each high-volume air sampler was obtained by use of the pitot tube and manometer.[5] The velocity pressure for each test run was taken at each sampling station. These data were used for calculations of air velocity and volume in each condenser exhaust. With the aid of the variable voltage transformer, the intake volume through the 2-inch orifice and high-volume sampler was adjusted to the desired reading between 0 to 70 ft^3/min and indicated on the visifloat of the sampler.

The filters used on the air samplers were Gelman type A glass fiber and were changed at the end of each test—one-bale lots with 10 to 12 minutes of sampling time. Because of the small size of the trapped particles, extreme care was exercised in the handling of the test filters so that samples would not be disturbed. The filters were conditioned in the laboratory for 24 hours at 60% relative humidity and 75° F, then weighed to the nearest milligram. Filter tare weights were determined on the clean filters conditioned in the same way.

After correcting the intake air volume to standard atmospheric conditions (70° F, 14.7 lb/in^2, 50% RH), the dust concentrations of the trash-laden air were calculated for the intake and exhaust of each inline filter. All dust concentrations were calculated in micrograms per cubic meter (μg/m^3). The collection efficiency of the inline filter was determined as follows:

$$\text{Collection efficiency (\%)} = \frac{\text{inlet concentration} - \text{outlet concentration}}{\text{inlet concentration}} \times 100.$$

The inline filters used in the 2-year study were commercial models having stationary screens and revolving brushes similar to the unit described by Alberson and Baker.[6] The filtering screen is

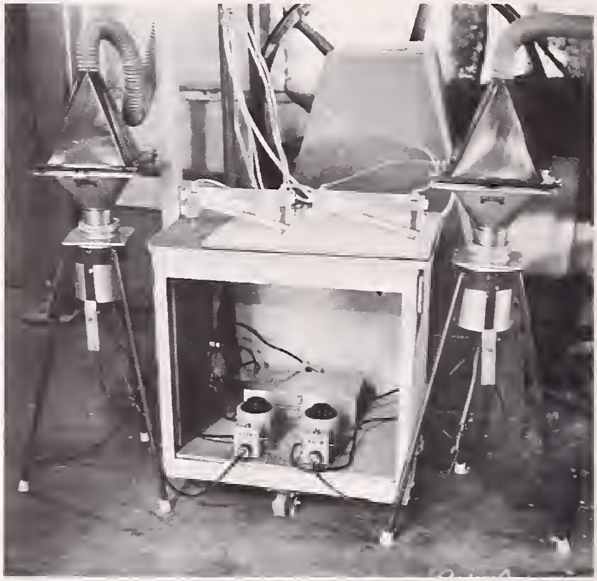

FIGURE 1.—Sampling station for determining the inlet dust concentrations to the inline filters.

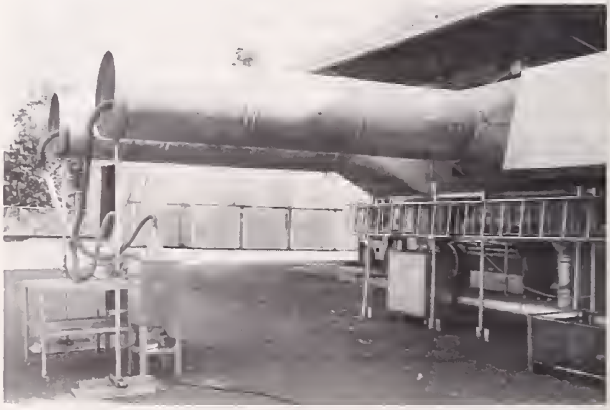

FIGURE 2.—Sampling station for determining the exhaust dust concentrations from the inline filters.

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[5] Isokinetic sampling is the condition in which the air velocity in the sampling orifice is exactly equal to the air velocity in the conduit being sampled.

[6] Cited in footnote 4.

mounted in a housing with a motorized brush controlled by a pressure-differential sensor. As dust and lint fly collect on the screen, back-pressure builds up to a threshold level that actuates the cleaning brush to sweep the screen clean of the collected dust and lint fly; then the collecting-cleaning cycle repeats. The filtering medium used was 0.0037-gage, 80- by 80-mesh, stainless-steel bolting-grade wire cloth having an open area of 49.6 percent.

All data were obtained with the inline filters located in either the battery condenser or lint cleaner exhausts. These filters were handling approximately 5,500 and 6,000 ft³/min of air, respectively. The filter in the battery condenser exhaust operated on a pressure differential of 0.35 inch, and the one in the lint cleaner exhaust operated on 1.00-inch pressure differential. The elapsed time between sweeps of the brush for the filter in the lint cleaner exhaust was dependent upon the stage of lint cleaning selected and ranged from 4 to 20 minutes. The time between sweeps ranged from 15 to 25 minutes for the filter in the battery condenser exhaust. The sampling period spanned a 6-week ginning season.

TEST RESULTS, 1970

To determine the collection efficiency of the inline filter located in the battery condenser exhaust, 75 bales of cotton were ginned at rates from 3.75 to 5.25 bales per hour per gin stand. The ginned lint passed through two stages of lint cleaning before entering the battery condenser.

The trash content of the incoming seed cotton was determined by fractionation tests on wagon samples, one taken from each bale, with two tests per sample. The composition of the seed cotton as determined by the fractionation tests was as follows:

Component	*Composition (%)*
Clean cotton	94.8
Large trash (>3,300 μm)	3.5
Small trash (<3,300 μm)	1.1
Invisible waste	.6
Total	100.0

Dust concentrations at the inlet and outlet of the inline filter located in the battery condenser exhaust and the collection efficiency of the inline filter are given in table 1. Statistical analysis of variance (complete random design) showed significant differences at the 1-percent probability level in the inlet dust concentrations to the filter; however, there were no significant differences in collection efficiency for the range of inlet dust concentrations tested.

To determine the composition of the material trapped by the glass fiber filters, analyses were made on 20 filters obtained from the sampling station between the battery condenser and the inline filter. Approximately 50 percent by weight of the material trapped was lint fly. A microscopic examination—oil-immersion method—of the sampler filters for exhaust air revealed that the inline filter was generally 100 percent efficient in removal of lint fly.

The collection efficiencies of the filters with respect to ginning rate indicate that variations in the ginning rate had no effect on the operational efficiency of the inline filters (table 2).

Data for subsequent tests were recorded for the two test bales processed between sweeping operations of the filter brushes. Examination of 10 glass fiber filters from bales immediately following the

TABLE 1.—*Efficiency of inline filter in battery condenser exhaust with respect to inlet dust concentration, 1970*

Inlet dust concentration (μg/m³)	Average dust concentration (μg/m³)		Collection efficiency (%)	Number of bales tested
	Inlet	Outlet		
8,000– 9,000	8,774	1,597	81.9	5
9,000–10,000	9,489	1,731	81.8	7
10,000–11,000	10,448	2,663	74.5	11
11,000–12,000	11,467	2,767	75.9	14
12,000–13,000	12,565	3,232	74.3	10
13,000–14,000	13,300	2,924	78.0	12
14,000–15,000	14,384	3,625	74.8	6
15,000–16,000	15,510	4,564	70.6	9
>16,000	17,416	3,115	82.1	1
Average	[1]12,191	[2]2,953	75.8	—

[1] Data represent an inlet rate of 0.25 pound per hour.

[2] Data represent an emission rate of 0.06 pound per hour.

sweep (table 3) indicate the collection efficiency of the inline filter unit ranged from 56.5 to 69.0 percent, with an average of 62.7 percent. Data obtained from sampling the second bale after the sweep (10 times, one-bale lots) revealed a range in collection efficiency from 75.6 to 93.7 percent, with an overall average of 84.0 percent. The difference in the average collection efficiency (84.0% − 62.7% = 21.3%) represents the additional filtering obtained by the buildup of lint fly on the inline filtering medium.

TABLE 2.—*Inline filter efficiency with respect to ginning rate, 1970*[1]

Ginning rate (bales/hour)	Average dust concentration (μg/m^3)		Collection efficiency (%)
	Inlet	Outlet	
3.75–4.25	13,086	3,517	73.1
4.25–4.75	12,268	2,804	77.1
4.75–5.25	12,309	3,568	71.0

[1] Data are the average of 10 samples.

TABLE 3.—*Inline filter efficiency after sweeping, 1970*[1]

Test condition	Dust concentration (μg/m^3)		Collection efficiency (%)
	Inlet	Outlet	
1st bale after sweeping	12,627	4,680	62.7
2nd bale after sweeping	12,404	2,018	84.0

[1] Data are the average of 10 tests.

TEST RESULTS, 1971

Eighty-four bales of cotton were ginned to determine the collection efficiency of the inline filter installed in the lint cleaner or battery condenser exhaust. The 84 bales consisted of three Southeastern cotton varieties—'Coker 201', 'Coker 310', and 'Dixie King'.

The valve and piping arrangements of the ginning system were designed so that the ginned lint could be routed through a lint cleaner that could be used as either the first, second, or third stage of lint cleaning. Data were collected from the inline filter operating in the exhaust of the various stages of lint cleaning. The battery condenser exhaust was sampled simultaneously for each bale processed through the selected stage of lint cleaning.

The trash content of the incoming seed cotton was determined by means of the fractionation test. The composition of the 84 bales of seed cotton used in the 1971 filter evaluation is as follows:

Component	*Composition (%)*
Clean cotton	92.1
Large trash (>3,300 μm)	5.7
Small trash (<3,300 μm)	1.3
Invisible waste	.9
Total	100.0

A summary of the data obtained from this experiment is given in table 4. The inlet concentration to the filter on the lint cleaner exhaust ranged from an average low of 11,342 μg/m^3 to an average high of 157,278 μg/m^3. The collection efficiency varied from a low of 76.4 to a high of 88.7 percent. Inlet dust concentrations to the battery condenser ranged from an average low of 7,676 μg/m^3 to an average high of 18,927 μg/m^3. Collection efficiencies of the inline filter in the battery condenser exhaust varied from 85.4 to 91.2 percent.

A summary of filter performance with respect to cotton variety and filter location is given in table 5. An analysis of variance of the collection efficiency of the inline filter when operating on the exhaust of either the second or third stage of lint cleaning revealed no significant difference with respect to either cotton variety or filter location at the 10-percent probability level.

Ranges of dust concentrations and the filter collection efficiency with respect to filter locations were determined (table 6). Data shown for the battery condenser were obtained while simultaneously sampling the condenser exhaust for the various selected stages of lint cleaning.

The composition of the mass entering the inline filter from the various stages of lint cleaning was determined. Eight filters were selected for each stage of lint cleaning. An approximate lint-trash ratio was obtained by processing the combined mass of lint from the eight filters for each stage of lint cleaning through a Shirley analyzer. The composition of lint in the emission from the first, second, and third stage of lint cleaning was 25, 45, and 50 percent, respectively. The low lint composition (25 percent) combined with the increased rate of sweeping accounts for the low collection efficiency (76.4 percent) recorded for the filter operating in the exhaust from the first stage of lint cleaning.

The dust concentration and the total emission rate for the battery condenser, sampled simultaneously for the various stages of lint cleaning, are shown in table 7. Also shown is the lint composition of the total emission as determined by Shirley analyzer tests and the equivalent lint emission in pounds per bale (500 pounds lint). The lint emission averaged 0.032 pound per bale.

Table 4.—*Efficiency of inline filters with respect to inlet dust concentration, 1971*

Inlet dust concentration range (μg/m³)	Lint cleaner exhaust				Battery condenser exhaust			
	Number bales sampled	Average dust concentration (μg/m³)		Collection efficiency (%)	Number bales sampled	Average dust concentration (μg/m³)		Collection efficiency (%)
		Inlet	Outlet			Inlet	Outlet	
6,000– 8,000	0	—	—	—	2	7,676	648	91.2
8,000–10,000	0	—	—	—	17	8,998	985	89.0
10,000–12,000	1	11,342	2,108	81.4	33	10,805	1,406	87.0
12,000–14,000	2	12,987	1,642	87.4	12	13,888	1,350	90.3
14,000–16,000	3	15,032	2,205	85.3	10	14,844	1,653	88.9
16,000–18,000	2	17,744	2,745	84.5	8	16,642	2,424	85.4
18,000–20,000	3	18,784	2,808	85.0	2	18,927	1,898	90.0
20,000–25,000	13	22,080	3,692	83.3	—	—	—	—
25,000–30,000	5	28,215	3,517	87.5	—	—	—	—
30,000–35,000	13	31,947	5,369	83.2	—	—	—	—
35,000–40,000	18	37,121	4,366	88.3	—	—	—	—
40,000–50,000	4	45,072	5,073	88.7	—	—	—	—
50,000–60,000	6	55,512	6,349	88.5	—	—	—	—
60,000–70,000	6	63,828	8,613	86.5	—	—	—	—
>70,000	8	157,278	37,098	[1]76.4	—	—	—	—

[1]Data obtained from the inline filter after only 1 stage of lint cleaning.

Table 5.—*Inline filter efficiency with respect to cotton variety and filter location, 1971*

Cotton variety	Number bales tested	Inline filter location											
		Lint cleaner No. 1			Lint cleaner No. 2			Lint cleaner No. 3			Battery condenser		
		Average dust concentration (μg/m³)		Collec. eff. (%)	Average dust concentration (μg/m³)		Collec. eff. (%)	Average dust concentration (μg/m³)		Collec. eff. (%)	Average dust concentration (μg/m³)		Collec. eff. (%)
		Inlet	Outlet		Inlet	Outlet		Inlet	Outlet		Inlet	Outlet	
'Coker 201'	8	157,278	37,098	76.4	—	—	—	—	—	—	16,044	2,894	82.0
Do	24	—	—	—	34,236	4,400	87.1	—	—	—	10,806	967	91.1
Do	9	—	—	—	—	—	—	23,089	2,680	88.4	11,028	1,278	88.4
'Coker 310'	11	—	—	—	30,035	5,581	81.4	—	—	—	12,034	1,690	86.0
Do	10	—	—	—	—	—	—	18,862	2,522	86.6	9,565	1,347	85.9
'Dixie King'	11	—	—	—	59,985	8,101	86.5	—	—	—	14,971	1,442	90.4
Do	11	—	—	—	—	—	—	33,842	5,019	85.1	11,048	1,317	88.1
Overall average		157,278	37,098	76.4	39,389	5,567	85.9	25,623	3,485	86.4	11,920	1,472	87.6

Table 6.—*Dust concentration and collection efficiency with respect to filter location, 1971*

Filter location	Number bales sampled	Dust concentration (μg/m³)						Average collection efficiency (%)
		Inlet			Outlet			
		High[1]	Low[2]	Average	High[1]	Low[2]	Average	
Lint cleaner No. 1	8	197,806	120,987	157,278	42,534	21,718	37,098	76.4
Lint cleaner No. 2	46	65,444	17,612	39,389	10,484	1,274	5,567	85.9
Lint cleaner No. 3	30	40,760	11,342	25,623	6,246	1,507	3,485	86.4
Battery condenser	84	18,979	7,648	11,920	3,631	425	1,472	87.6

[1]Highest single emission of all tests.

[2]Lowest single emission of all tests.

TABLE 7.—*Dust concentrations and emissions from the battery condenser, sampled simultaneously with a preselected stage of lint cleaning, 1971*

Stage of lint cleaning	Number bales sampled	Dust concentration ($\mu g/m^3$)	Total[1] emission (lb/bale)	Lint composition[2] (%)	Lint emission (lb/bale)
1	8	16,044	0.067	59.7	0.040
2	46	12,096	.050	64.4	.032
3	30	10,548	.044	69.3	.030
Average		11,920	.050	64.5	.032

[1] Total emission was determined using an airflow of 5,000 ft^3/min, a processing rate of 4.5 bales per hour per gin stand, a bale weight of 500 pounds and a conventional condenser not covered with fine-mesh wire.

[2] Determined by Shirley analyzer tests.

CONCLUSIONS

Data obtained in the 1970 experiment revealed the following:

1. The average collection efficiency of the inline filter for the bales tested was 75.8 percent.

2. The inlet dust concentration to the filter had no significant effect on the collection efficiency of the filter. Varying the ginning rate from 3.75 to 5.25 bales per hour did not have a significant effect on the collection efficiency of the inline filter.

3. Lint fly made up approximately 50 percent by weight of the material entering the inline filtering unit. A microscopic examination of the material emitted from the inline filter indicated that it operated at virtually 100-percent efficiency on lint fly.

Experiments in 1971 resulted in the following significant findings:

1. The average collection efficiency of the inline filter operating after the various stages of lint cleaning varied from 76.4 to 86.4 percent. Filter efficiency in the battery condenser exhaust ranged from 82.0 to 91.1 percent, averaging 87.6 percent.

2. The collection efficiency of the inline filter on the exhaust of the second or third stages of lint cleaning was not significantly affected by either cotton variety or filter location.

3. The lint composition of the trash-laden air entering the inline filter from the first, second, and third stage of lint cleaning was found to be 25, 45, and 50 percent, respectively.

4. The total dust emission rate from the battery condenser exhaust for the 84 bales sampled averaged 0.05 pound per bale. Lint fly accounted for an average of 64.5 percent of this total emission, or the equivalent of 0.032 pound per bale.

The data obtained during the 2 years indicate the inline filter will satisfactorily collect the dust and lint fly from condenser exhausts in the Southeast.

*1976-G.P.O. 1750-S/671-583/39

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